Process and Device for Biological Treatment of a Suspension in a Bioreactor with Integrated Hydraulic Bottom Layer Removal

Cross Reference To Related Application

This application is related to a concurrently filed application entitled "Process and Device For Biological Treatment Of A Suspension In A Bioreactor With Integrated Hydraulic Top Scum Treatment" (Attorney Docket No. LINDE-0616) by the identical inventors. Priority is claimed of DE 10358400.5.

The invention relates to a process for biological treatment of a suspension in a bioreactor that has a central outlet area near the bottom and in which to circulate the suspension at least some of the suspension is routed through a substantially vertically aligned guide zone so that a substantially vertical flow of at least a portion of the suspension is produced, which flow extends into the vicinity of the bottom of the bioreactor or proceeds from the vicinity of the bottom of the bioreactor, as well as a device for carrying out the process.

Processes for biological treatment of suspensions are, e.g., aerobic or anaerobic processes for biological treatment of waste water, sewage sludge or waste, in which the biodegradable substances that are contained in the suspension are decomposed by microorganisms.

Processes for biogas recovery are defined below as the anaerobic treatment of suspensions containing biodegradable materials, especially the fermentation of waste or sludge digestion in the treatment of sewage sludge. The biodegradable materials that are

also called fermentation media are fermented into biogas in a bioreactor called a fermentation reactor with the exclusion of air. Often mechanical stirring systems or hydraulic recirculation systems are used to thoroughly mix the fermentation medium in the fermentation reactor. Injecting gas into the vicinity of the bottom of the fermentation reactor is also used in various ways.

In so-called loop reactors, a gas is injected into the central guide pipe that is located within the fermentation reactor, by which the fermentation medium is drawn into the guide pipe. In this way, e.g., the fermentation medium can be conveyed by the guide pipe from the vicinity of the bottom of the fermentation reactor to the surface of the fermentation medium that is contained in the fermentation reactor. Thus, at least most of the fermentation medium can be circulated in the fermentation reactor. Such a system is described in, e.g., DE 197 25 823 A1. In addition to the important feature that there are no moving parts in the fermentation reactor, this system offers still other advantages. For example, low-gradient, thorough mixing is achieved via the vertical loop. Moreover, the possibility of integrating a heat exchanger into the fermentation reactor in the form of a double-jacketed pipe through which hot water flows is offered. By blowing gas into the loop flow and the associated surface surge formation and turbulent bottom mixing, in the surface flow that is pointed radially outward, moreover, the formation of surface scum is controlled. As a result of the defined flow conditions near the bottom for sediment transport in the direction of the central bottom outlet, the formation of sediment deposits is also prevented.

In practical operation, however, it has been shown that for special sludge and waste qualities that are supplied to the fermentation reactor in a system-specific manner, surface layer and sediment problems can occur that require additional control measures.

This relates, on the one hand, to sludges with a higher content of detergents and fine-fibrous plastic and cellulose particles, as they result from community waste water treatment or special commercial organic residues, as well as more highly viscous sludges; the mass proportions that are larger depending on origin contain glass fragments and other irregularly shaped inert particles.

For the initial materials, flotational skimming can take place with collection in the outer area of the fermentation surface in the reactor where the radially decaying turbulence is no longer sufficient for bottom mixing. For sediments that are dissimilar to sand (rounded quartz grains), entanglement of the particles by their irregular fracture edges can occur; this means increased resistance to hydraulic transport to the center bottom discharge point.

Objects of the invention are to configure a process and apparatus of the initially mentioned type such that the sediment problems are ameliorated.

Upon further study of the disclosure, other objects and advantages of the invention will become apparent.

From a process standpoint, the sediment problem is ameliorated by feeding a substantially horizontal flow superimposed on the substantially vertical flow in the vicinity of the bottom of the bioreactor, by which a spiral flow to the central outlet area of the bioreactor is established.

The basic idea of the invention therefore comprises superimposing a hydraulic jet system on the gas-induced loop reactor principle. In this way, the process-engineering advantages of a loop reactor with a guide pipe and gas injection can be used and at the same time problem cases that occur depending on the media are controlled by cyclic operation of the hydraulic system without significantly increasing the addition of energy to the bioreactor system.

A free liquid jet injected into the bioreactor in the area of the bottom causes rotation of the liquid mass near the bottom. A spiral flow to the reactor center is formed from the superposition of the liquid flow of the vertical reactor loop, which flow is pointed downstream and in the vicinity of the bottom toward the center, on rotation near the bottom. The additional flow in the area of the reactor near the wall, where the loop flow is least and thus sediment deposits become possible, supports particle transport toward the middle of the reactor into the withdrawal area. This is achieved by the so-called "teacup effect" since according to the Bernoulli equation, a local pressure drop in this direction is formed.

In bioreactors with up to 8000 m^3/h of reaction volume and diameters of up to 22 m, it is sufficient to deliver the fluid into the bioreactor with a flow velocity of from 10 to 15 m/s, preferably as a free liquid jet. Moreover, the fluid is preferably fed into the bioreactor with a volumetric flow rate of from 300 to 600 m^3/h. In this way, the necessary pulsed flow is produced in order to have the liquid mass near the bottom rotate at roughly 0.5 m/s near the tank wall. Furthermore, it has proven especially favorable to feed the fluid into the bioreactor at an extension angle to the radius jet of from 40° to 60° in order

to induce the necessary torque. Furthermore, a tilt angle to the horizontal from 0 and 10° should be set to compensate for the media-induced buoyancy forces in the jet field (gas inclusions). Advantageously, a portion of the suspension that is suctioned off from the bioreactor and is preferably fed into the bioreactor as a free liquid jet via a nozzle is used as the fluid.

For irregularly shaped solid particles, the global liquid motion is not sufficient to lift the sedimented particles again. Surprisingly enough, however, it was found that in the area of the active free jet region with a local velocity of greater than the average liquid velocity, bottom sediments are clearly reduced compared to the other deposition area. Here, the conformity to the laws of debris motion takes effect, in which according to the "Magnus effect," rolling particle motion on the bottom induces a vertical buoyancy force on the particle that lifts it locally and thus again moves it into the flow field that is pointed toward the center.

In the sum of these motion processes, sediments near the edge move toward the reactor middle. These effects are supported by a tilt built into the bottom foundation toward the tank center between preferably 10 to 20° in order to be able to use conventional foundation-laying techniques.

The free liquid jet is advantageously produced via an externally mounted pump that withdraws the required amount of liquid from the reactor and transports it back again via the nozzle.

In order to ensure the described Magnus effect over the entire periphery of the tank, the fluid is preferably fed into the bioreactor via several nozzles that are distributed

in the vicinity of the bottom on the periphery of the bioreactor. Depending on the reactor size, there are between 1 and 5 nozzles at the corresponding distances on the periphery of the bioreactor.

Simultaneous operation of the nozzles would mean two to five times the energy consumption for the supplementary hydraulic system. Surprisingly enough, however, it was found that the described effect can also be recorded for time-staggered operation of the bottom nozzles since particles that have settled in the meantime can again be further transported according to the effect. According to one especially preferred embodiment of the invention, therefore, all installed nozzles are connected to one pump and are successively supplied from the latter by means of cyclic switching. This makes possible an efficient and low-maintenance mode of operation.

If defined circulation of sedimentable particles from the bioreactor is required, a hydrocyclone that is dimensioned according to the desired degree of settling can be incorporated into the pump line for the free jet system. Advantageously then, the intake line of the pump is routed toward the center of the bottom of the bioreactor where the media fraction that is enriched with sediment is located.

According to a further development of the idea of the invention, intensified top scum treatment takes place likewise via nozzle systems that are located near the surface on the periphery of the tank. Here, the fluid that is suctioned off from the bioreactor is fed into the bioreactor in part or in a time sequence in addition via at least one nozzle provided in the area of the suspension fill level such that the surface of the suspension and/or the top scum floating on the surface of the suspension is forced into rotary flow.

Preferably, the fluid is fed into the bioreactor via nozzles that are located substantially tangentially on the periphery of the tank. Here, the nozzles can be supplied from the same pump as the nozzles located in the vicinity of the bottom. Such a hydraulic connection via the bottom nozzle pump is especially recommended when the on cycles are evaluated as too little and one or two additional operating cycles can be assigned to the bottom system. When the top scum nozzles are working frequently because of the nature of the media, conversely a separate pump should be preferred.

The top scum and foam particles that accumulate in the vicinity of the periphery of the tank have the tendency to stick together and compact over the longer term. They must therefore be continually wetted and kept slippery, must be agitated when they combine, and adhesively adhering gas bubbles must be eliminated in order to reduce the buoyancy. Optionally, deflection into the vicinity of the surface must be possible.

Complete control over the entire reactor periphery is not technologically feasible since steel fermentation reactors are generally not designed for the fill level in the area of the roof slope in terms of strength. Thus, the free liquid surface corresponds to the cross-sectional area of the cylindrical reactor part.

According to an especially preferred embodiment of the invention, the problem is solved in that the top scum that has been pushed together externally into a ring by the radial surface flow from the guide zone to the edge of the tank is exposed hydraulically to free liquid jets by preferably at least one nozzle located tangentially on the periphery of the tank and is forced into circulation by means of the transferred pulses. In doing so, the

top scum ring runs through the jet zones and is wetted and agitated here in the desired manner.

The top scum outlet attached radially to the inside wall of the tank with a drop pipe that can be pushed away at the level of the liquid surface feasibly enables removal of floating material that can no longer be stirred into the suspension as necessary. The conditions can be adjusted by a change in the fill level in the bioreactor such that either the top scum rotates over the outlet or the material is pushed into the outlet box in batches.

To do this, preferably a nozzle with dimensions analogous to the bottom nozzles is located at a distance in front of the top scum outlet such that it washes the material into the outlet box with sufficient momentum.

Preferably, there is a second nozzle opposite that provides for movement and wetting. Advantageously, operation of the two nozzles likewise takes place cyclically.

In addition to the process for biological treatment of a suspension, the invention also relates to a device for biological treatment of a suspension with a bioreactor for receiving the suspension, in the interior of the bioreactor there being a guide means that extends into the vicinity of the bottom of the bioreactor with a vertical alignment for circulating the suspension.

Apparatus to perform the process comprises at least one nozzle for feeding a fluid into the bioreactor in the vicinity of the bottom of the bioreactor.

The nozzle can advantageously be supplied with the suspension via a feed line that is connected to the interior of the bioreactor and via a pump. Preferably, there are several

nozzles distributed in the vicinity of the bottom on the periphery of the bioreactor. Here, the nozzles are preferably connected to a common pump. To compensate for the media-induced buoyancy forces, the nozzles are preferably arranged with a tilt angle against the horizontal between 0 and 10°.

A further development of the device according to the invention calls for the feed line connected to the interior of the bioreactor to be connected in addition to a nozzle located in the area of the intended suspension fill level for feeding fluid into the bioreactor. Here, the nozzle is advantageously arranged tangentially on the tank periphery. The nozzle is advantageously connected to the same pump as the nozzle that is located in the vicinity of the bottom of the bioreactor.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following preferred specific embodiment is, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

Brief Description of Drawing

The invention will be explained in more detail below based on the embodiment that is shown diagrammatically in the figure.

The figure shows, a plant for fermentation of wet garbage, for example. The wet garbage is processed in pretreatment steps that are not shown in the figure such that pulp or hydrolysate is formed. The pulp or the hydrolysate is supplied to the bioreactor that is labelled as the fermentation reactor 2 via a line 1 as a suspension that is called the

fermentation medium. In the fermentation reactor 2, methanation of the pulp or the hydrolysate is carried out. To do this, the fermentation reactor 2 is kept under anaerobic conditions, and the contents of the fermentation reactor are circulated. The anaerobic biomass contained in the fermenting pulp or the hydrolysate converts the organic substances partially into carbon dioxide and methane. The resulting biogas is drawn off from the fermentation reactor 2 via line 3.

Since the pulp or the hydrolysate also contains sulfur compounds, H_2S would also be formed without further measures and would be found again ultimately in the biogas. In order to minimize the undesirable H_2S portions in the biogas, the entire contents of the fermentation reactor defined by an oxygen-containing zone are transported with sufficient contact time between the oxygen-containing gas and fermentation medium. For this purpose, the fermentation reactor 2 is made as a loop reactor with an inside loop in the form of a centrally and vertically arranged guide pipe 5 that acts as the oxygen-containing zone. Here, the biogas that is pumped into the lower part of the interior of the guide pipe and that is branched off from the biogas discharge line 3 via the biogas branch line 6 is used as a propellant gas. As a result of the decrease in the density of the mixture in the guide pipe 5 and the gas buoyancy force, the fermentation medium is conveyed from bottom to top through the guide pipe 5. In doing so, the hydraulic conditions are set by choosing the guide pipe geometry and the injected biogas flow, such that the entire contents of the fermentation reactor are pumped at least twice per hour through the guide pipe 5. Air is metered into the inner ascending flow of the guide pipe 5 by means of an air feed line 7 in quantitative ratios such that the fermentation medium adequately

acquires oxygen contact during passage through the guide pipe 5 in order to limit H_2S formation in its metabolic processes in the desired manner. At the same time, the oxygen is decomposed biochemically to such an extent that there are no longer any oxygen portions that adversely affect the process in the biogas. The air demand can thus be minimized such that the nitrogen in the biogas does not lead to a significant diminishment of gas quality for further caloric use. To maintain an operating temperature that is optimum for biological treatment of the fermentation medium, the guide pipe 5 is made to be heated. To do this, the guide pipe 5 is provided with a double-walled jacket that has a feed 8 and discharge 9 for the heating water. In addition or alternatively, the contents of the fermentation reactor can be temperature-treated by means of an outside heat exchanger 19 through which the heating water flows.

To control the problem cases that occur specific to the media, especially sediment problems that arise for special sludge and waste qualities, a hydraulic jet system is superimposed on the gas-induced loop reactor principle. In this way, the process-engineering advantages of the loop reactor with a guide pipe 5 and gas injection 7 can be used, and at the same time problems that arise specific to the media can be solved without significantly increasing the addition of energy into the fermentation system. For this purpose, the fermentation medium is drawn off from the fermentation reactor 2 via line 15 and pump 16 and supplied to a nozzle 11 via line 12.

The fermentation medium as a free liquid jet is fed into the fermentation reactor 2 via the nozzle 11 with a nozzle velocity from 10 to 15 m/s and a volumetric flow rate of from 300 to 600 m^3/h in the area near the bottom. In fermentation reactors with up to

8000 m^3 of reaction volume and diameters of up to 24 m, the necessary pulsed flow is produced in this way in order to have the liquid mass near the bottom rotate at roughly 0.5 m/s near the tank wall. Here, the nozzle 11 that has a diameter of from 50 to 120 mm, depending on the tank size and the process parameters, is offset by 40^o to 60^o to radial flow in order to induce torque. A sufficient tilt angle of the nozzle 11 to the horizontal of between 0 and 10^o is employed to compensate for the media-induced buoyancy forces in the jet field. In practice, between two and five nozzles are arranged at corresponding distances on the periphery over the entire fermentation reactor tank circumference, depending on the reactor size. For the sake of clarity, the figure shows only one nozzle 11. All of the installed nozzles are connected to a single pump, specifically the pump 16, and are successively supplied from the latter by means of cyclic switching of the series. This makes possible an efficient and low-maintenance mode of operation.

In order to control top scum problems, a branch line 14 leads from the pump 16 to a nozzle 13 that is located on the fermentation reactor tank circumference near the surface. The hydraulic connection of this nozzle 13 takes place via the pump 16 when the on cycles are evaluated as too little and one or two additional operating cycles can be assigned to the bottom system. When the nozzle 13 is working frequently because of the nature of the media, a separate pump is to be preferred. Like the nozzles 11 located in the vicinity of the bottom, it is also recommended with respect to the nozzle 13 located near the surface that there be several nozzles. For the sake of clarity, however, only one nozzle 13 is shown in the figure.

In the above description, the bottom part of the reactor is below the bottom of the tubular reactor 5.

The entire disclosures of all applications, patents and publications, cited herein are incorporated by reference herein.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.